CHONDRULE SERPENTINES AS INDICATORS OF AQUEOUS ALTERATION IN CM CARBONACEOUS CHONDRITES N. P. Hanowski and A. J. Brearley, Institute of Meteoritics, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131.

Introduction

Carbonaceous CM chondrites are complex meteorites which exhibit widely varying degrees of aqueous alteration and brecciation. These processes have produced heterogeneous alteration assemblages with diverse mineral compositions and alteration textures. Previous attempts to constrain the degree of alteration and to develop an alteration sequence for CM chondrites have largely focused on the compositional behavior of matrix and/or matrix minerals, such as, serpentine as a function of increasing alteration [1-4]. This approach, however, is not without problems. Compositional analyses of matrix material are strongly depended on the method of sampling and analysis [5], such as the use of different electron beam sizes [4,6]. The effects of polymict brecciation on the matrix heterogeneity are also difficult to constrain and have been neglected. Finally, various definitions have been in use to define matrix in various studies (e.g. including or excluding rim material) [4,5,7]. Analytical studies by electron microprobe and TEM show that both matrix and matrix serpentine compositions show extremely wide compositional ranges within individual CM chondrites. As a consequence, attempts to use matrix and matrix serpentine compositions to define an alteration sequence for the CM chondrites are compromised by the significant compositional overlap from one CM chondrite to another [5]. Here we present an alternative approach for constraining the alteration degree of CM chondrites based on the alteration mineralogy and mineral compositions of different chondrule types in CM chondrites. This approach also enables us to assess the effects resulting from brecciation. Individual chondrules represent systems whose primary textural and mineralogical characteristics are much better constrained than in matrix. Our goal has been to understand how specific chondrule types respond to progressive aqueous alteration by studying their alteration assemblages in CM chondrites with varying degrees of aqueous alteration and brecciation. The preliminary results of our study indicate that this approach has considerable promise in establishing a precise alteration sequence for the CM chondrites. We selected well-defined chondrule types (e.g. IA, IAB and IIA [8]) from the CM chondrites: **Murray, Murchison, Mighei, LEW 90500, Nogoya, ALH 81002** and **ALH 84034** for our electron microprobe analyses (employing a 1μm beam at 15kV). Mesostasis in chondrules of all the CM chondrites studied has been completely altered whereas the replacement of primary crystalline silicates progressively increases from Murray to ALH 84034. Our results show that type IAB chondrules with occurrences of Ca-pyroxene crystallites in the altered mesostasis and type IIA chondrules with diameters between 100μm and 300μm show remarkably systematic behavior, whereas type IA chondrules display more complexity.

Results

Serpentines which have replaced mesostasis in type IAB and IIA chondrules in the CM chondrites studied generally show an increase in Mg content which is correlated with textural evidence for advancing aqueous alteration (such as increasing silicate replacement). For the least altered CM chondrites, **Murray** and **Murchison** mesostasis serpentines show limited ranges of Fe-rich serpentine (cronstedtite) compositions along the cronstedtite-antigorite mixing line in the ternary Fe-Si-Mg diagram. Murchison mesostasis serpentines, however, are slightly more Mg-rich in both chondrule types (e.g. for type IAB chondrules: $Mg/(Mg+Fe)_{IAB}$=0.15-0.25) than in Murray ($Mg/(Mg+Fe)_{IAB}$=0.12-0.17). Chondrules in these meteorites contain abundant Ca-pyroxene microcrystallites in the former mesostasis which have escaped alteration. **Mighei** and **LEW 90500** mesostasis serpentines show a wide compositional spread along the same mixing line, but with an increased Mg content (Mighei: $Mg/(Mg+Fe)_{IAB}$=0.23-0.39) and (LEW 90500: $Mg/(Mg+Fe)_{IAB}$=0.19-0.36). LEW 90500 type IAB and type IIA chondrules, however, are clearly distinct from chondrules in Mighei due to the presence of a second, compositionally-distinct, Mg-serpentine (Mg/(Mg+Fe)= 0.47-0.57) which is the product of advanced alteration of enstatite and fayalitic olivine phenocrysts. Ca-pyroxene microcrystallites are much less common in the former mesostasis of these meteorites than in Murray or Murchison. **Nogoya** shows the widest spread in type IAB and IIA chondrule serpentine compositions of all CM chondrites under study ($Mg/(Mg+Fe)_{IAB}$=0.17-0.57). The spread is largely due to compositional variations between different chondrules whereas analyses from individual chondrules display only a limited range (typically $\Delta Mg/(Mg+Fe)<0.1$). Mesostasis serpentine compositions in **ALH 81002**, a meteorite which shows a well-preserved primary accretionary texture, have a limited

range in type IIA and, especially, type IAB chondrules ($Mg/(Mg+Fe)_{IAB}$=0.30-0.38). These characteristic serpentines coexist with Mg-rich serpentines (Mg/(Mg+Fe)=0.48-0.57) which have pseudomorphically replaced fayalite, enstatite and forsterite phenocrysts. Chondrules in **ALH 84034** are characterized by the almost complete absence of any unaltered precursor phases [9] and serpentine compositions are generally Mg-rich (Mg/(Mg+Fe)>0.45). Inspection of backscattered electron images of the complete thin sections for all these chondrites indicates a significant degree of post-alteration brecciation for the meteorites Mighei, LEW 90500 and Nogoya. Of these meteorites Nogoya shows the highest abundance of clasts and coarse-grained components with variable degrees of alteration, such as highly and only slightly altered type IIA chondrules.

Conclusions

Our observations demonstrate that progressive replacement of primary chondrule phases with increasing alteration degree in the CM chondrites under study is generally accompanied by the occurrence of increasingly more Mg-rich serpentines replacing mesostasis. This observation suggests that as alteration proceeds, mesostasis compositions become more Mg-rich, presumably due to equilibration with a more Mg-rich fluid which is the result of more advanced silicate dissolution. An increased abundance of Mg-rich serpentines due to advancing crystalline silicate alteration facilitates the distinction between different alteration degrees. The unbrecciated meteorite ALH 81002 shows only restricted chondrule serpentine compositions and a very uniform degree of chondrule alteration throughout the section. The advanced alteration in this CM chondrite did not require brecciation for the alteration process as indicated by its undisturbed primary accretionary appearance. These observations on ALH 81002, clearly show that models which directly link brecciation and aqueous alteration processes [1,2,5] are not applicable to all CM chondrites. All compositional trends of chondrule serpentines in type IAB chondrules are consistent with those in type IIA chondrules and we conclude that the analyzed sections represent a distinct sequence towards higher degrees of aqueous alteration in the order: Murray, Murchison, Mighei, LEW 90500, ALH 81002 and ALH 84034 (Fig.1). Due to the extreme compositional variability of average serpentine compositions between different chondrules in Nogoya no rank is assigned although highly altered material appears to dominate. This variability of serpentine compositions present in different chondrules of the same type within a single thin section appears to be correlated with increasing evidence for polymict brecciation from LEW 90500 and Mighei to Nogoya. Mighei appears to be somewhat anomalous in having a mesostasis serpentine Mg/(Mg+Fe) ratio higher than is consistent with the degree of alteration exhibited by the primary chondrule crystal phases. A possible explanation for the unexpectedly high Mg content of Mighei mesostasis serpentine compared to LEW 90500 may involve a higher Mg content of the altering fluid as a result of brecciation related and more intensive crystalline silicate comminution and alteration. The relevance of such a process for the serpentine compositions, however has not been quantitatively constrained and needs further investigation.

References

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Fig.1 Mg/(Mg+Fe) in type IAB chondrule serpentines (from mesostasis and crystal alteration).